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**Alex Krister Raith
INVENTOR**

SYSTEM AND METHOD FOR IMPROVING CHANNEL MONITORING IN A CELLULAR SYSTEM

COATS & BENNETT, P.L.L.C.
P.O. Box 5
Raleigh, NC 27602
(919) 854-1844

1 SYSTEM AND METHOD FOR IMPROVING CHANNEL MONITORING IN A
2 CELLULAR SYSTEM

3

4 BACKGROUND OF THE INVENTION

5 The present invention relates generally to the management of mobile stations in a
6 wireless communication system and, more particularly, to a system and method for
7 providing improved channel selection procedures.

8 In a wireless communication system, the service area is typically divided into a
9 plurality of cells, with each cell served by a base station. Mobile stations within a
10 particular cell communicate over RF channels with the base station serving that cell. The
11 base station may handle a plurality of simultaneous calls from mobile stations. The base
12 stations are connected with one another and to the public switched telephone network by
13 mobile services switching centers (MSC). The MSC coordinates the activities of all the
14 associated base stations and connects the entire cellular system to the public switched
15 telephone network. A typical MSC may handle 100,000 cellular subscribers and 5,000
16 simultaneous conversations at a time. The MSC also accommodates billing and system
17 maintenance functions. In some higher density networks, several MSCs are used in a
18 single network.

19 During the course of a call, the mobile station may move from one cell into
20 another. A switching technique called a handoff enables the call to proceed uninterrupted
21 when the user moves between cells. When the mobile station moves into a different cell
22 while a call is in progress, the MSC automatically transfers the call from the current
23 channel being used to a new channel belonging to the base station serving the new cell.

24 Processing handoffs is an important task in any wireless communication system.
25 Handoffs ensure that acceptable signal quality standards are maintained as the mobile

1 station moves out of range of one base station and into the radio coverage area of another
2 base station. Handoffs should be performed successfully and be imperceptible to the
3 user. Also, because of the signaling demand a handoff places on the system, handoffs
4 should be performed as infrequently as possible and only as needed.

5 Handoff decisions are typically based on received radio signal strength and
6 channel quality as monitored by the base station serving the mobile station. Received
7 signal strengths are easily monitored and signal quality for any given channel is often
8 determined by the bit error rate (BER) over a given channel. During any communication
9 period, the cellular system will continually seek a better channel and cell for
10 communications. A handoff from the current channel to another channel is initiated
11 when the signal level or channel quality drops below acceptable levels and another
12 channel is available capable of providing acceptable communications.

13 In digital systems, such as Global System for Mobile communications (GSM) and
14 Time Division Multiple Access (TDMA) systems, the base stations enlist the assistance
15 of the mobile station to determine when a handoff is required. In order to use a mobile
16 station to assist handoff, the serving base station downloads a list of channels, commonly
17 referred to as a neighbor list, at the start of a call or after a handoff. The neighbor list
18 identifies channels in neighboring cells which are potential handover targets. In a mobile
19 assisted handoff (MAHO), each mobile station measures the received power from
20 surrounding base stations provided by the neighbor list, which is also referred to as a
21 MAHO list. The mobile station continually reports the results of these measurements to
22 the serving base station. These reports are often referred to as MAHO reports. The
23 signal strength measurements are made by the mobile station in between periods of

1 communication during a call. For example, in GSM systems, each radio frequency
2 channel is divided into eight time slots. In TDMA systems, each radio frequency channel
3 is divided into six slots. The mobile station is allocated one time slot for transmissions
4 and another time slot to receive signals from the base station. During the remaining time
5 slots, the mobile station is not communicating with the serving base station. The mobile
6 station monitors channels belonging to neighboring base stations during these idle
7 periods and then quickly returns to its assigned channels in time to transmit and receive
8 signals in its allocated time slot. The measurements made by the mobile station of
9 signals received from neighboring cells are reported back to the serving base station in a
10 scheduled manner or on a separate channel so as not to interfere with voice or data
11 transmissions. During multi-slot operation, the time slots normally used for
12 communications are “borrowed” to allow the mobile station to report measurements to
13 the base station. This concept is typically referred to as frame stealing and reduces
14 transmission rates.

15 The measurement reports provided by the mobile station give the base station a
16 list of the signal strength and possibly channel quality from adjacent cells, as measured
17 by the mobile station at its present location. The network also knows which adjacent
18 cells have unused radio channels that are available for allocation during a handoff. From
19 the list of available channels, the network selects the cell which best will handle the call
20 from a service quality and an overall interference point of view based on signal strength
21 and bit error rate. A suitable traffic channel is assigned that cell as the target, and the
22 mobile station is commanded to return to the traffic channel in the target cell. At the
23 same time, the call is switched by the MSC to the base station currently serving the

1 mobile station to the base station ~~in the target cell~~. The mobile station switches to the
2 newly assigned channel during one of the idle periods so there is no interruption in
3 transmission. Thus, from the user's perspective, the handover is seamless.

4 Cell reselection is the process of changing channels for service and registering
5 with a new base station when the mobile station is not active. When the mobile station is
6 between calls and not actively communicating with a base station, but is ready to receive
7 or place calls, it monitors one or more control channels of proximate base stations to
8 receive paging or other instructions. This state of operation is commonly referred to as
9 the idle state or idle mode. Since there is no two-way communication in place while in
10 idle mode, the cellular system does not know which base station the mobile station
11 should monitor. Typically, the mobile station monitors signal strength along with other
12 indicia indicative of channel quality in order to select a base station. In older analog
13 systems, the selected base station was typically the one providing the strongest signal. In
14 modern digital systems supporting hierarchical cell structures, the mobile station
15 performs a much more elaborate evaluation of candidate cells.

16 As the mobile station moves throughout areas of coverage for various base
17 stations, it acquires information about channels and their attributes used or associated
18 with surrounding base stations by reading a list of channels sent on a broadcast channel
19 for each cell from which it is able to receive information. This list is also commonly
20 referred to as a neighbor list. The neighbor list identifies specific channels for the mobile
21 station to monitor when idle. In essence, the mobile station monitors the listed channels
22 and decides on the best channel for service. When the mobile station decides a new

1 channel is required, it may send information to the new base station to register and effect
2 cell reselection.

3 While idle, mobile stations make a tradeoff between accurate neighbor list
4 measurements and energy consumption. U.S. patent number 5,539,748 entitled
5 Enhanced Sleep Mode in Radio Communication Systems discloses a few basic
6 techniques to reduce the neighbor list measurements without sacrificing the quality of
7 these measurements. In essence, the patent describes a very basic system-assisted and a
8 mobile station-controlled method for reducing the number of neighbor list measurements.

9 In the former, the cellular system sends the mobile station the minimum, nominal
10 frequency and measurement for each entry in the neighbor list. The cellular system
11 provides an indication that certain entries can be measured with a reduced frequency.
12 This is applicable if there are many entries in the neighbor list or the entries are in a
13 hierarchical cell layout. In the latter, the mobile allows a reduced measurement
14 frequency from the nominal requirement if no cell reselection has been performed for a
15 specified time. Alternatively, the measurement is reduced if changes of signal strength
16 for the serving control channel and neighbor list entries are less than specified.

17 A significant amount of system resources and power are used while assisting a
18 base station during handoffs and monitoring nearby stations for cell reselection. Given
19 the premiums placed on getting the most use of allocated bandwidth and extending
20 battery life, there is a need for an improved channel selection system and method to
21 reduce processing time and energy consumption associated with channel selection during
22 active and idle modes without degrading performance.

23

SUMMARY OF THE INVENTION

2 In recent years, the cost of manufacturing a global positioning system (GPS)
3 receiver has been reduced to a level that makes it practical to incorporate GPS receivers
4 into consumer electronics. A mobile station equipped with a GPS receiver or similar
5 position determining electronics could provide accurate position information to the
6 mobile station and associated network to assist the network in system management
7 functions, and in particular, assist with channel selection.

8 The present invention relates to a mobile station capable of determining its current
9 location within a wireless communication system. The mobile station periodically
10 generates an estimate of its current location or mobility and then monitors channels for
11 channel selection based thereon in order to minimize frame stealing while in active mode
12 and save energy during idle mode. The same information is also useful for determining
13 which cells to monitor and controlling how frequently position or changes of position
14 estimates are made. Although the invention requires a determination of the mobile
15 station's position or mobility, the manner in which the mobile station determines these
16 characteristics may vary. A separate positioning receiver, which receives signals from a
17 terrestrial or satellite station, may allow the mobile station to calculate its position.
18 Alternatively, the mobile station may monitor signals provided during communications
19 with the base stations to calculate a relative position. In yet another embodiment, the
20 base stations and associated cellular systems may cooperate to determine a particular
21 mobile station's position and then download the position to the mobile station. Those
22 skilled in the art will recognize numerous techniques for identifying a mobile station's
23 position or mobility and use that information according to the teachings of the present

1 invention. Existing and future position and mobility determining means are considered
2 within the scope of the invention.

3 Accordingly, each cell in the neighbor or MAHO list may be measured with an
4 independent measurement frequency varying from a nominal default to zero. The
5 cellular system may assist the mobile station with position-related attributes to the entries
6 on the neighbor and MAHO list, such as the position of neighboring cells and the position
7 of the base station's transmitter for that cell. This information, although not limited to, is
8 preferably transmitted on the broadcast channel in a neighbor list or a point-to-point
9 channel in a MAHO list message.

10 These and other aspects of the present invention will become apparent to those
11 skilled in the art after a reading of the following description of the preferred embodiment
12 when considered with the drawings.

13

14 BRIEF DESCRIPTION OF THE DRAWINGS

15 Figure 1 is a schematic representation of a cellular network.

16 Figure 2A is a block diagram of a telephone embodiment of a mobile terminal
17 with a positioning receiver.

18 Figure 2B is a block diagram of an alternative embodiment of a mobile terminal.

19 Figure 3 is a representation of cellular layout having omni-directional cells with
20 distinct areas defined therein.

21 Figure 4 is a representation of cellular layout having sectorized cells with distinct
22 areas defined therein.

1 Figure 5 is a flow chart outlining the basic process for improving channel
2 selection and monitoring during active and idle modes.

3

4 DETAILED DESCRIPTION OF THE INVENTION

5 In the following description, like reference characters designate like or
6 corresponding parts throughout the several views. Referring now to the drawings, the
7 improved channel selection method of the present invention is described. Channel
8 selection according to the present invention is useful in mobile cellular systems like that
9 shown schematically in Figure 1. The mobile cellular system, which is indicated
10 generally by the numeral 10, includes a plurality of base stations 12, which are connected
11 via a mobile services switching center (MSC) 14 to a terrestrial communications network
12 such as the Public Switched Telephone Network (PSTN) 18. Each base station 12 is
13 located in and provides service to a geographic region referred to as a cell. In general,
14 there is one base station 12 for each cell within a given system. Within each cell, there
15 may be a plurality of mobile stations 16 that communicate via a radio link with the base
16 station 12. The base station 12 allows the user of the mobile station 16 to communicate
17 with other mobile stations 16, or with users connected to the PSTN 18. The mobile
18 services switching center 14 routes calls to and from the mobile station 16 through the
19 appropriate base station 12. Information concerning the location and activity status of the
20 mobile station 16 is stored in a Home Location Register (HLR) 20 and a Visitor Location
21 Register (VLR) 22, which are connected to the MSC 14.

22 It is worth noting that a different architecture is often used for packet data
23 sessions, such as that used in GPRS and Mobile IP. As such, there may be no

1 involvement from the MSC 14. In essence, the base station 12 is connected to a packet
2 data node, and then to the public packet data network through additional nodes to reach
3 the internet. Furthermore, the concepts of the present invention are applicable to all
4 current and future wireless communication systems, including cdma2000 and WCDMA.

5 Figure 2A is a block diagram of a mobile station 16 adapted to receive position
6 indicia. In particular, the disclosed embodiment of the mobile station 16 is a fully
7 functional cellular telephone, such as an IS95 compliant cellular telephone, capable of
8 transmitting and receiving signals. The cellular telephone 16 includes a control unit 22,
9 which is typically a microcontroller-based system for controlling the operation of the
10 cellular telephone 16, and a memory 24 for storing control programs and data used by the
11 cellular telephone 16 during operation. Input/output circuits 26 interface the
12 microprocessor 22 with a keypad 28, a display 30, audio processing circuits 32, receiver
13 38, transmitter 40, and positioning receiver 50. The keypad 28 allows the operator to dial
14 numbers, enter commands, and select options. The display 30 allows the operator to see
15 dialed digits, stored information, and call status information. The audio processing
16 circuits 32 provide basic analog audio outputs to a speaker 34 and accept analog audio
17 inputs from a microphone 36. The receiver 38 and transmitter 40 receive and transmit
18 signals using a shared antenna 44. The positioning receiver 50, which may for example
19 be a Global Positioning System (GPS) receiver, enables the mobile station 16 to
20 determine its current location based on positioning signals transmitted by a GPS satellite.
21 The receiver 50 requires an antenna, which may be separate from or integrated with the
22 mobile station's antenna. The positioning receiver 50 could also be designed to receive
23 similar positioning signals from terrestrial sources.

1 Alternatively, the mobile station 16 may be configured to determine a relative
2 position or mobility based on signals received from one or more base stations 12. For
3 example, the cellular system may determine the mobile station's position or mobility
4 using triangulation or similar positioning techniques and then download the mobile
5 station's position to the mobile station 16. Alternatively, the mobile station 16 may use
6 its communication and control electronics to monitor signals received from one or more
7 base stations and calculate its relative position or mobility, also using triangulation or like
8 techniques. Such a system is shown in figure 2B without a separate receiver for
9 positioning estimating.

10 The mobile station 16 is programmed to periodically monitor selected control
11 channels in adjacent cells and to perform channel quality measurements on those
12 channels. Channel quality measurements may include received signal strength, bit error
13 rate (BER), and word error rate (WER), as well as other parameters. Channel quality
14 measurements may, for example, be transmitted by the mobile station 16 to the base
15 station 12 to assist the base station 12 in making hand-off determinations. Hand-offs
16 made by the base station 12 on the basis of channel quality measurements made by the
17 mobile station 16 are known as mobile assisted hand-offs. Channel quality
18 measurements may also be used by the mobile station for cell reselection. Cell
19 reselection may occur, for example, when the mobile station 16 is in a idle mode or
20 engaged in a packet data session.

21 According to the present invention, the mobile station 16 is programmed vary the
22 frequency at which channel quality measurements are made based on the position of the
23 mobile station 16, or some function of that position. For example, the mobile station 16

1 may be programmed to determine its position relative to the currently serving base station
2 12 and vary the frequency of the channel quality measurements as a function of the
3 distance from the serving base station 12. In this case, the frequency of channel quality
4 measurements would increase as the distance from the serving base station increased. In
5 another embodiment, the mobile station 16 may determine its position relative to the
6 serving base station 12 and a target base station 12 in a neighboring cell and vary the
7 frequency of measurement as a function of the distance from both base stations 12. In
8 this case, the frequency of reporting may be dependent on the ratio of the distances
9 between the serving base station and the target base station 12. Another embodiment
10 would be to monitor the position of the base station 12 and vary the frequency of channel
11 quality measurements based on the mobility of the mobile station 16. For purposes of
12 this application, the term mobility is defined to be any function of position and time, such
13 as the rate of change in position of the mobile station 16 over time. Another example of
14 mobility would be the amount of time the mobile station 16 stays in one position. In this
15 case, the frequency of channel quality measurements would increase with increasing
16 mobility.

17 While the disclosed embodiment relates to the performance of channel quality
18 measurements by the mobile station, those skilled in the art will recognize that the
19 present invention could be adapted for other channel monitoring functions, or any other
20 periodic tasks that need to be performed by the mobile station. Also, those skilled in the
21 art will recognize that the frequency of the channel monitoring functions could also be
22 dependent on other factors, in addition to position or mobility.

23

1 By adjusting the frequency of reporting in an intelligent manner, it is possible to
2 minimize the amount of frame stealing required during active mode and reduce
3 monitoring activities during idle mode to conserve energy. Importantly, the measurement
4 procedures according to the present invention avoid or minimize any impact on the
5 quality of handoff or cell reselection procedures. In essence, handoffs and cell
6 reselection should take place at about the same time and to the same cell as that provided
7 by existing channel selection procedures. The primary difference is reduced frame
8 stealing and decreased energy consumption.

9 To implement the present invention, the mobile station 16 must estimate its
10 position periodically. The need to estimate position may potentially conflict with the
11 objective of saving battery life while in idle mode. However, there may be other
12 applications that dictate the need for position estimates, such as for acquiring a position
13 used in emergency calling. Furthermore, the frequency of making position estimates may
14 be one or more magnitude less than channel selection measurements. If no mobility is
15 detected and hence, very infrequent neighbor list measurements and position estimates
16 are made, there is a net gain in battery life. During active mode, the object is to minimize
17 required frame stealing and not the frequency of measurement per se. Hence, during
18 active mode, the battery drain due to performing position estimates is a secondary issue.

19 The basic process for improving channel selection and monitoring during active
20 and idle modes is outlined immediately below in association with the flow chart of Figure
21 5. The process begins (block 100) when a call is initiated or a handoff occurs (block
22 102). A mobile station 16 (MS) receives a neighbor list or MAHO list (block 104)
23 outlining channels associated with surrounding cells, which are to be monitored by the

1 mobile station 16. At any point during this process, the mobile station 16 periodically
2 determines its estimated position and/or mobility (block 106). Notably, position or
3 mobility determinations need not occur at the channel monitoring frequency or a
4 frequency dependent on how often the mobile station 16 monitors channels from the
5 neighbor or MAHO list. Also, it should be noted that position estimating is a periodic
6 function and that the frequency at which the position of the mobile station 16 is updated
7 could also vary in accordance with the present invention. Thus, the mobile station 16
8 could be programmed to perform additional calculations to update the frequency of
9 position estimating after updating its current position, or to determine a time at which to
10 update its current position.

11 While the mobile station 16 is actively handling a call, it monitors the channels on
12 the MAHO list at a frequency depending on the mobile station's position or mobility
13 (block 108). Preferably, the position or mobility determinations also bear on which
14 channels to monitor, and possibly, which to avoid. Notably, the frequency at which the
15 mobile station 16 monitors these channels may also be influenced by other factors, such
16 as the current state of the call, the type of call, etc. Further details regarding these factors
17 are outlined below. During this time, the mobile station 16 also monitors signals from
18 the base station serving the mobile station 16 for handoff instructions (block 110).
19 Assuming the call continues, the mobile station 16 will determine whether or not to
20 change channels based on the handoff information from the base station, or in certain
21 proposed systems such as DECT, the mobile station 16 may make the determination
22 independently and signal the cellular system accordingly (block 114). As noted above, in

1 most digital systems, the handoff decision is made by the serving base station with the
2 assistance of the mobile station 16.

3 If a handoff (block 114) is not required, the mobile station 16 repeats the process
4 of determining its position or mobility and continues monitoring the channels on the
5 neighbor or MAHO list based thereon. If a handoff is required, the system typically
6 downloads a new MAHO list and repeats the above processes accordingly.

7 When a call ends (block 112), the mobile station 16 typically changes from an
8 active mode of operation to an idle mode. During idle mode, the mobile station 16 is still
9 served by a base station in the sense that it selects a base station for registration purposes
10 and transmits signals to the serving base station to effect such registration. When idle,
11 the mobile station 16 typically determines when cell reselection is necessary and effects
12 new registration any time channels or cells are changed.

13 Assuming a call is not received or the mobile station 16 is not required to set up a
14 new call (block 116), the mobile station 16 downloads neighbor lists from the serving
15 base station, and perhaps, lists from other base stations providing signals of sufficient
16 strength and quality (block 120). During this process, the mobile station 16 periodically
17 determines its position or mobility (block 122). Based on this determination, the mobile
18 station 16 monitors the channels from the neighbor list with a frequency depending
19 on position or mobility (block 124). As discussed further below, the mobile station 16 may
20 receive access to information bearing on the position of the serving and surrounding base
21 stations as well as coordinates defining areas served by select channels within a cell.
22 Given certain or all of this information, the mobile station 16 may control the frequency
23 of measurements and the channels to measure based on its relative position to a single

1 base station, relative position between two base station, or its relative position within a
2 defined area or cell.

3 Sub 16
B When mobility is a variable controlling these measurements, the mobile station 16
4 may base these measurements on mobility alone, relative to a single base station 12,
5 relative to multiple base stations 12, or combine a mobility determination with relative
6 position to one or more areas or cells. The frequency at which these channels are
7 monitored or which channels are monitored are also subject to influence by other factors,
8 such as signal strength, signal quality, etc. The mobile station 16 then determines
9 whether or not to change serving cell for cell reselection based on the monitoring of the
10 channels on the neighbor list and the serving base station (block 126). If cell reselection
11 occurs, the mobile station 16 may be required to register with the cellular system in order
12 to identify its presence in the new paging area if necessary. The process will repeat until a
13 new call is arranged or the phone is completely powered down.

14 The mobile station 16 communicates with the base station 12 using a
15 communications channel. The term channel can have various meanings depending on the
16 context. In general, an RF channel refers to a single allocation of a contiguous spectrum.
17 In the AMPS and IS-136 systems, an RF channel is a 30 kHz allocation in the 850 MHz
18 band or the 1900 MHz band. In GSM, an RF channel is a 200 kHz in the 900 or 1950
19 MHz bands and 1800 MHz for GSM. The term channel may also refer to an information
20 channel (control channel or traffic channel) in a TDMA or CDMA system. In a TDMA
21 system, an information channel comprises one or more time slots on an RF channel that
22 are allocated to a mobile station 16 for transmitting and receiving. In a CDMA system,
23 an information channel is distinguished by an unique coding scheme that further

1 subdivides the RF channel. For purposes of this application, the term communications
2 channel or channel will generally refer to an information channel, which could be the
3 same as an RF channel in some systems.

4 There are essentially two types of cellular communication techniques, circuit-
5 switched and packet-switched. A circuit-switched connection is a circuit connection that
6 is established and maintained, usually on demand, between two or more stations to allow
7 the exclusive use of the circuit until the connection is released. A packet-switched
8 connection is a logical connection that is established between two or more stations to
9 allow the routing and transfer of data in the form of packets. The channel is occupied
10 during the transmission of a packet only. Upon completion of the transmission, the
11 channel is made available for the transmission of other packets for the same or other
12 stations. Channel selection procedures typically vary depending on whether circuit-
13 switched or packet-switched connections are used.

14 For circuit-switched data communications, mobile-assisted handoffs are typically
15 used where the mobile assists with measurements and the cellular system controls
16 channel allocation. Since the mobile station 16 is continuously allocated an uplink
17 channel, as for a voice call, measurement reports are typically sent on a call-associated
18 control channel. In contrast, during a packet data session, the mobile station 16 does not
19 transmit for extensive periods. During these packet sessions, sending a mobile-assisted
20 handoff report would unnecessarily use uplink channels shared by multiple mobile
21 stations 16. Thus, packet data protocols typically specify that the mobile station 16 finds
22 the best channel and the cellular system relinquishes control in order to save bandwidth.

1 The process of allocating the mobile station 16 to the best base station 12 during
2 an active packet data session is similar or identical to the cell reselection process while in
3 idle mode. A neighbor list is received from the cellular system and the mobile system
4 measures and evaluates the candidate cells based on channel quality. In order to maintain
5 conciseness and readability, the terms neighbor list and MAHO list are used to refer to
6 any type of measurement list identifying channels or base stations to monitor. These
7 terms are used to facilitate an understanding of the invention by associating a neighbor
8 list with idle operation and packet data operation and a MAHO list for active operation.
9 However, these terms are interchangeable and each may be used to describe
10 measurement lists for active and idle modes. As such the disclosure and claims should be
11 interpreted accordingly. Nothing prevents a hybrid solution in which the mobile station
12 16 performs cell reselection measurement and selection and the cellular system overrides
13 the default cell reselection process by sending a handoff command. Notably, the GPRS
14 packet data protocols in GSM systems support mobile station 16 and network-initiated
15 cell reselection.

16 There are implications for letting the mobile station 16 evaluate neighboring cells.
17 The particular implication depends on whether the mobile station 16 is operating in active
18 or idle mode. For TDMA systems operating in active mode, the number of time slots per
19 TDMA frame is large enough such that there is ample amount of time for the mobile
20 station 16, during non-assigned time slots, to perform neighbor list (or MAHO list)
21 measurements. However, for multi-slot operation, such as when all slots are allocated,
22 there is no spare time for neighbor list or MAHO list measurements. During idle mode,
23 availability of time slots is not an issue. The primary objective for the mobile station 16

1 is to minimize current consumption while successfully monitoring the assigned
2 communication channel and performing neighbor list measurements.

3 Numerous techniques exist for minimizing the impact of these constraints. For
4 example, when mobile station 16 is operating in active mode and a time is available for
5 MAHO list measurements, either a second receiver is used to assist in communications or
6 the mobile station 16 stops transmitting or receiving data on one or more slots and uses
7 the slots to perform the list measurement. The latter is referred to as frame stealing,
8 which inherently reduces communication throughput.

9 Communication protocols include retransmission of lost data, but this reduces the
10 efficiency of the system. The tradeoff is typically loss of throughput versus measurement
11 accuracy.

12 Frame stealing is typically one of two types: scheduled stealing or wild stealing.
13 For scheduled stealing, the system sends time information specifying when the mobile
14 station 16 is allowed to or requested to perform neighbor or MAHO list measurements;
15 the system stops sending data during that time frame. In contrast, wild stealing is when
16 the mobile system makes an autonomous decision to perform neighbor or MAHO list
17 measurements without providing any information to the cellular system. Arming the
18 cellular system with information relating to when the mobile station 16 is not available
19 for data reception and transmission improves system throughput. Frame stealing is
20 adaptable to either circuit-switched or packet-switched connections.

21 For circuit-switched connections, there is typically a minimum number of
22 measurements required for any given time period and for each entry in a measurement list
23 in order to maintain the quality of the channel quality measurement (CQM) report, if it is

1 addressed at all in the protocol/standard. Further, a maximum number of frames are
2 allowed to be stolen. This is done to maximize the time the mobile is allowed to make
3 specific measurements in order to put a limit on the reduction of data throughput. These
4 are conflicting requirements, which require efficient use of the mobile station 16 to
5 provide scheduled or wild stealing.

6 Both types of stealing are also applicable for packet-switched connections.
7 Further details regarding scheduled and wild frame stealing in packet-switched
8 connections is provided in U.S. patent entitled Apparatus and Method for Signal Strength
9 Measurement in a Wireless Communication System, which is incorporated herein by
10 reference.

11 Both GSM (GPRS) and ANSI-136 incorporate some or all of the aspects (i.e.
12 stealing) mentioned above in order to handle neighbor and MAHO list measurements in
13 active mode while in multi-slot operation. For a CDMA system, the availability of time
14 for neighbor and MAHO list measurements is typically not an issue as long as these
15 measurements are restricted to channels on the same frequency as the communication
16 channel.

17 The neighbor list and MAHO list may contain sub-lists for a defined area. That
18 is, the neighbor list or MAHO list may incorporate one or more area definitions defining
19 at least partially distinct areas. A sub-list would then be associated with each area
20 definition. Each sub-list may contain different neighbor and MAHO entries or one entry
21 may appear in several sub-lists. An example format of a list may be: area definition 1,
22 channel entries for area 1, attributes for cell 1; area definition 2, channel entries for Area
23 2, attributes for cell 2; ..., area M definition, channel entries for area M, attributes for cell

1 M. The attributes may include cell identity, service capability and the exact position of
2 the base station's transmitter for the given cell. U.S. patent number 5,353,332 relates to
3 providing information about other cells and is incorporated herein by reference.

4 Figures 3 and 4 show exemplary sub-division of cells into multiple areas. A
5 specified area, according to the information transmitted from the cellular system, may
6 overlap and cross the hypothetical cell areas defined as hexagons. Turning now to figure
7 3 in particular, omni-directional cells are assumed. For base station B1, there are three
8 areas. The first area is the area with radius R1, the second is the area within radius R2,
9 but not within the first area defined by R1. The third area is outside the circle defined by
10 radius R2. The base station B1 transmits information defining radius R1, radius R2, and
11 the position of its transmitter.

12 Base station B2 is configured differently and transmits coordinates in groups to
13 define areas. The first area is defined within coordinates P1, P2, P3, P4, P5 and P6. The
14 second area is defined within coordinates P5, P6 and P7. A third area is defined within
15 coordinates P5, P6, P7, P8 and P9. A fourth area is any position not covered by the other
16 three areas. Preferably, the base station B2 transmits the coordinates P1 through P9 and
17 the above area definitions to the mobile station 16.

18 Another configuration is shown associated with base station B3 where four areas
19 are defined. The first area is defined by radius R3. A second area is to the west (left) of
20 line L1, and a third area is defined by the area east (right) of L2. A fourth area is defined
21 by the remaining portions not covered by the three other areas.

22 Yet another exemplary configuration is shown associated with base station B4
23 where three areas are defined. The first area is east (right) of the line L3, and a second

1 area is west (left) of the line L3. A third area is defined by radius R4 from a particular
2 coordinate P1. Mobile stations 16 not subscribing to the system simply skip measuring
3 those entries. A configuration similar to that defined by B4 may also be of interest when
4 private systems are located within a cell. Thus, the channel entries for the area associated
5 with radius R4 may include one or more channels belonging to private systems. Base
6 station B4 may transmit the coordinates, line definitions and groupings, as do the other
7 base stations. Furthermore, for the area defined by radius R4, the identity and definitions
8 of private systems may be included with the channels to measure.

9 Figure 4 is exemplary of systems using sectorized cells. As depicted, each base
10 station has three sectors: S1, S2 and S3. For base station B5, one area is defined by the
11 coordinates P11, P12 and P13. Another area is defined with coordinates P11, P12 and
12 P10, the latter of which is the position of the base station. Yet another area is defined
13 west (left) of line L6 and north (above) line L5. Another area is defined east (right) of L6
14 and north (above) line L2, but not defined by the first two areas of coverage. Two
15 additional areas are defined using the remaining coordinates defined by the lines L5 and
16 L6. These coordinates, line definitions and the interpretations are transmitted by base
17 station B1.

18 As exemplified above, areas of interest may be defined in many different forms.
19 For example, a set of coordinates and hypothetically connected constituents in an area.
20 Another example is a distance from the position of a cell thereby defining areas as
21 concentric circles. The center position of the receptive cell may also be included as a
22 defined area.

1 In a preferred embodiment, once a mobile station 16 has determined its position it
2 may 1) measure all the entries associated with the area containing the mobile station 16
3 based upon its position; 2) measure other entries, such as areas neighboring the identified
4 area, with a lesser frequency; or 3) not measure some entries at all. The latter alternative
5 is preferably saved for non-adjacent areas. These decisions are preferably made in
6 association with information pertaining to cell configuration, such as defined by the areas
7 exemplified above. Importantly, any input or information from which position or
8 mobility may be derived is equally well suited for both active and idle modes of
9 operation.

10 The degree of measurement relaxation or change may depend on several factors
11 alone or in combination with one another. These factors include change in position
12 between position estimates; estimated speed, relative position of the mobile station 16 to
13 a serving cell and respective neighboring cells, or time spent in a current state. The latter
14 of which is preferably used while other inputs, such as position or speed are
15 approximately constant. Certain of these factors may be beyond any currently specified
16 protocol standards or rules of measurement, e.g. broadcasting area specific NL. This
17 information may be transmitted to the mobile station 16 using sub-lists and used in
18 association with specified measurement rules.

19 If mobility is determined, measurement procedures may be affected in numerous
20 ways. The most preferable of these would be to: 1) immediately revoke all measurement
21 relaxation; 2) gracefully revoke relaxation; 3) revoke measurement relaxation dependent
22 on the degree of mobility; or 4) revoke measurement relaxation dependent on the relative
23 position of the mobile station 16 to a current and/or respective neighboring cells. For

1 example, if the mobile station 16 is very close to the base station of the serving cell, it
2 will typically take a while for the mobile to reach a signal strength border and before a
3 geographic or more preferable the radio border reselection would take place. If the
4 mobile station 16 has the position of the neighboring base station, it can calculate the
5 time required with an assumed speed before it reaches the cell border. This time,
6 assuming a conservatively high speed, can be used to set the degree of measurement
7 relaxation and how quickly to react when mobility is detected.

8 As another example, assume the mobile station 16 is engaged in a packet data
9 session and is multi-slot capable, such as an eight-slot GPRS mobile station 16. As such,
10 the mobile station 16 must sometimes stop Rx or Tx or both data in order to fulfill a
11 required neighbor cell measurement procedure. This necessarily results in reduced data
12 rate throughput. However, for most instances of packet data operation resulting in a high
13 data transfer rate, the user is not traveling. For example, a user could download
14 information from the Internet while sitting in an airport, meeting room, hotel lobby or
15 office. The mobile station 16 may use position estimates over time to determine that it is
16 not moving. The likelihood that a channel change is required, which is the reason to
17 make these measurements in the first place, is relatively low. The longer the mobile
18 station 16 determines that it is not moving, the more likely that for the next period of time
19 there will not be any movement and channel selection measurements can be further
20 relaxed. Thus, the time the mobile station 16 stays in a current state or position may
21 affect the frequency of cell measurements. Based on the position or mobility within a
22 cell or an area within a cell, the mobile may change the frequency channel measurements
23 are made and, perhaps, the cells that are monitored.

1 It is worth noting that cell reselection may take place when a mobile station 16 is
2 well within the cell's geographic border because of signal propagation effects caused by
3 shadowing from buildings and hills. Furthermore, in a hierarchical cell structure, cell
4 reselection may take place between cells that transmit from the same position. To this
5 end, a safety margin is preferred when activating and deactivating the measurement
6 relaxation. The mobile station 16 may use measurements of neighboring cells to predict,
7 using relative signal strength, how close it is to a potential cell reselection or handover.

8 As noted, in circuit switched mode the cellular system typically determines which
9 cell or channel to use. The system may handoff a mobile station 16 because of load
10 sharing between base stations or sectors therein or the channel may be subject to severe
11 interference for which an intra-cell handoff may be advantageous. In principal, the
12 mobile should not second-guess the system. Thus, care should be taken when
13 determining how aggressively the measurement relaxation is implemented by the mobile
14 station 16 vendor while in circuit switched mode.

15 In idle mode the situation is more easily controlled since the only things that
16 affect cell reselection are the measurements made by the mobile station 16 and a few
17 static parameters sent over broadcast channels. Thus, in idle mode, the mobile can make
18 more reliable predictions. For example, the mobile station 16 may determine that if a
19 neighbor list entry is 10 dB stronger than the current channel, then it will make a cell
20 reselection. It is important to realize that the inputs described above, in addition to
21 affecting cell reselection, may also affect the frequency of making position estimates
22 during active and idle modes to the extent other applications provide.

1 Certain modifications and improvements will occur to those skilled in the art upon
2 a reading of the foregoing description. It should be understood that all such
3 modifications and improvements have been deleted herein for the sake of conciseness and
4 readability but are properly within the scope of the following claims.

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